Remarks

Claims 1-5, 7-57, 73, 75-81, 96 and 98-121 are presently pending.

Claims 15, 22-57, 73, 75-81, 83-96, 101, 102, 107-111 and 113-121 have been withdrawn from further consideration.

Rejection of Claims under 35 U.S.C. § 102(b) (Aronowitz)

The Examiner maintains the rejection of Claims 1, 5, 7, 8, 18, 98-100, 103 and 106 under Section 102(b) as anticipated by Aronowitz (USP 6,087,229). This rejection is respectfully traversed.

The Examiner argues that Aronowitz discloses forming a nitride 'barrier' layer as claimed, citing particularly to the intermediate silicon nitride layer (**206**) in **Fig. 2D** – which the Examiner argues intrinsically (inherently) inhibits the passage of a dopant into the dielectric material, stating as follows (e.g., pages 2-3, bridging paragraph; emphasis added).

> ...and exposing the silicon layer to a nitrogen-containing gas to nitridize the silicon layer to form a continuous silicon nitride *dopant* *diffusion* barrier layer 206 ...to inhibit passage of a dopant (not: this is the intrinsic properties of the nitride material, *also see col. 8, first paragraph and lines 27-34; further in this regard, the intrinsic properties of the nitride material is evidence by Sugita et al., US/6,998,303, col. 2, lines 60-66)* therethrough into the dielectric material (fig. 2D)...

The Examiner cites to USP 6,998,303 (Sugita) at col. 2, lines 60-66, as evidence of the intrinsic properties of the nitride material (layer **206**) of Aronowitz as a barrier layer.

The Examiner has essentially taken "official notice" of the inherency of Aronowitz' intermediate SiN layer 206 (Fig. 2D) as a dopant barrier layer, based on Sugita's disclosure.

However, official notice of facts should be based on a *prior art reference*. See MPEP 2144.03: Reliance on Common Knowledge in the Art or "Well Known" Prior Art,

> It would not be appropriate for the examiner to take official notice of facts *without citing a prior art reference* where the facts asserted to be well known are not capable of instant and unquestionable demonstration as being well-known. For example, assertions of technical facts in the areas of esoteric technology or specific knowledge of the prior art must always be *supported by citation to some reference work recognized as standard in the pertinent art. In re Ahlert*, 424 F.2d at 1091, 165 USPQ at 420-21. See also *In re Grose*, 592 F.2d 1161, 1167-68, 201 USPQ 57, 63 (CCPA 1979) ("[W]hen the PTO seeks to rely upon a chemical theory, in establishing a prima facie case of obviousness, it must provide evidentiary support for the existence and meaning of that theory.")....

Sugita is <u>not</u> prior art to the application. Sugita was filed August *2003*. This application was a filing date of August ***2001***. Therefore, Sugita has been *improperly cited* by the Examiner.

Furthermore, even if, *arguendo*, one *were* to consider Sugita's disclosure, it does <u>not</u> support the Examiner's argument that the intermediate silicon nitride layer (**206**) in **Fig. 2D** of Aronowitz is *inherently* effective as a dopant (boron) diffusion layer.

Sugita's disclosure at col. 2, lines 60-66, states that a silicon nitride film having a thickness of 0.5 to 1 nm can be formed between a gate insulating film and polysilicon film to suppress boron diffusion (emphasis added).

> The processes up to the state shown in FIG. 1B will be described. A polysilicon film is deposited on the gate insulating film 5 to a thickness of 40 to 120 nm. *In order to suppress the diffusion of boron, a silicon nitride film or silicon oxynitride film having a thickness of 0.5 to 1 nm may be formed between the gate insulating film 5 and polysilicon film.*

Sugita provides no information other than the *thickness* of the silicon nitride film.

This teaching does not establish that the intermediate silicon nitride layer (**206**) in **Fig. 2D** of *Aronowitz* is *necessarily* and *inherently* an effective dopant (boron) diffusion layer.

The Examiner has provided no evidence of the intrinsic properties of the nitride material (layer **206**; **Fig. 2D**) of Aronowitz as a barrier layer.

As Applicant previously pointed out, Aronowitz' intermediate silicon nitride layer (**206**) in **Fig. 2D** is formed merely by implanting nitrogen into a silicon layer *without* performing an <u>anneal</u> required to form a boron diffusion layer (*as evidenced, for example, by **USP 6,410,968*** (Powell et al.)).

Again, the Examiner is directed to **Fig. 2D** (below), which illustrates Aronowitz' formation of intermediate silicon nitride layer **206**.

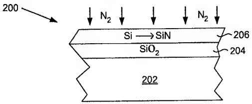

FIG. 2D

To form the intermediate silicon nitride layer **206** (**Fig. 2D**), Aronowitz *implants nitrogen* into the silicon layer. Aronowitz does not perform a subsequent anneal to form the intermediate SiN material **206** into an effective boron diffusion barrier.

See Aronowitz at col. 5, line 57 to col. 6, line 34, as follows.

> The thin silicon film 206 may then be nitridized, as shown in FIG. 2D. According to a preferred embodiment of the present invention, the wafer 200 may be introduced into a plasma reactor (not shown), such as one that is normally used for plasma etching of polysilicon. Suitable reactors can generate a plasma density and energy appropriate for the creation of ionic species having energies sufficient to break silicon-silicon bonds and penetrate the surface of the polysilicon film 206 without substantially damaging its structure. A relatively high density, such as about $10^{10}/cm^3$ to $10^{13}/cm^3$, and low energy, such as less than about 12 eV, preferably between about 5 and 10 eV, which can be separately controlled by the reactor, are preferred. The LAM 9400SE is an example of such a reactor. Molecular nitrogen may be introduced into the reactor to form the plasma containing nitrogen species which have energies of less than about 20 eV, and which are sufficient to break silicon-silicon bonds *so that these nitrogen* (atomic and/or molecular) *entities react at the surface of the polysilicon film 206* and within *several atomic layers into the film* producing a *nitrogen-rich surface region* in the polysilicon film 206.
>
> ...
>
> For example, a LAM 9400SE reactor may be operated according to the following process parameters to achieve nitridization of a thin amorphous or poly silicon film deposited on an oxide, according to a preferred embodiment of the present invention: pressure of about 10 mtorr; N_2 flow rate of about 10 standard cubic centimeters per minute (sccm); TCP power of about 200 W; bias power of about 10 W; electrode temperature of about 60°C.; backside He pressure of about 8 torr; step time of about 10 minutes. Using these parameters, a plasma with about 10 eV nitrogen species may be produced resulting in nitridization of the thin silicon film to about 25 to 30 atomic percent.

Following the nitridization step (**Fig. 2D**), Aronowitz then teaches oxidizing the *intermediate* nitrogen-rich silicon layer **206** to convert it into a nitrogen-rich oxide (SIO_xN_y) layer **206** in **Fig. 2E.**

No anneal of the intermediate SiN material 206 is performed or taught by Aronowitz. Rather, Aronowitz directly oxidizes the intermediate SiN layer.

As previously presented by Applicant, the need for an anneal to form an effective 'dopant diffusion barrier layer' by nitridation of silicon material is evidenced, for example, by **USP 6,410,968** (Powell et al.).

See again at col. 3, lines 8-43 below (emphasis added).

> ...A silicon-containing material is vapor deposited onto the surface of the wafer at block 203 from a silicon source. *The silicon-containing material is treated or processed using rapid thermal nitridation (RTN) in an NH_3 ambient* at block 204 resulting in creation of the barrier layer. The temperature, anneal time and processing pressure are selected to obtain desired barrier layer characteristics. ...
>
> ...FIG. 2B illustrates that *a suitable barrier layer may be formed at about 450 Torr and 850°C.*, over a processing time of 60 seconds with minimal oxidation of the underlying silicon substrate. It is noted that the 850°C. processing temperature is lower than *the processing temperature (typically 950°C.) used to create barrier layers using conventional methods*. In addition, the 60 seconds processing time is lower that the processing time used to create barrier layers using conventional methods (typically 45 minutes). ...
>
> *Generally, conventional barrier layers are processed using temperature ranges of 700°C. to 1050°C.*, processing time of 10 seconds to 60 minutes, and processing pressure of 760 torr. Whereas, the barrier layer of the present invention is typically processed using temperature ranges of *500°C. to 900°C.*, processing time of 30 seconds to 5 minutes, and processing pressure of 450 torr. ...

The need for an anneal is further evidenced by US 2008/0268634 (Yang) – at paragraphs **[0007]** and **[0021]** (below), which teaches implanting nitrogen and *annealing* the structure to form a boron diffusion barrier layer (at the interface between an Si layer and oxide layer).

> [0021] ...*Diffusion barrier layer 214 is formed by* implanting nitrogen into interface region 205 between silicon layer 206 and buried oxide layer 204 *and annealing 212 (FIG. 7) structure 200 to form diffusion barrier layer 214* between buried oxide layer 204 and silicon layer 206. As shown in FIGS. 6-7, oxygen 208 (FIG. 6) and *nitrogen* 210 (FIG. 7) are *implanted* into structure 200 following the formation of silicon layer 206. This oxygen/nitrogen ion beam implantation process is *followed by a high temperature anneal* 212 (FIG. 7) *to create* buried SiO_2 layer 204 and *diffusion barrier layer* 214, respectively. Diffusion barrier layer 214 effectively inhibits the diffusion of boron into regions underlying diffusion barrier layer 214.

Merely implanting nitrogen into silicon by Aronowitz' conditions does not inherently produce an effective boron barrier layer. As evidenced above, an anneal of the intermediate SiN layer **406 (Fig. 2D)** would be required to form an effective dopant barrier.

The Examiner has failed to fairly consider Aronowitz's teachings – and Applicant's previous submissions.

The Examiner also argues that Aronowitz's disclosure at *col. 8, first paragraph (lines 1-16) and lines 27-34*, is further evidence of the *intrinsic* dopant barrier properties of Aronowitz' *intermediate* SiN layer **406 (Fig. 2D)**.

However – that section of Aronowitz addresses the silicon ***oxy*nitride** SiO_xN$_y$ layer **406** illustrated in ***Fig. 4D*** – *not* the *intermediate* silicon **nitride** SiN layer **406** of ***Fig. 2D***.

See **Fig. 4D** and col. 8, lines 1-16 and 17-25, as follows (emphasis added).

400

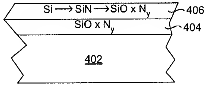

FIG. 4D

> ...Alternatively, as shown in **FIG. 4D**, the thin silicon layer **406** may also be subjected to low energy plasma nitridization **and then oxidized** *to create* a thin composite dielectric having *two **oxynitride** layers*. ***This second procedure*** provides the added benefit of preventing deterioration in dielectric properties ***by providing a nitrogen barrier to diffusion of boron*** from the gate electrode into the dielectric...
>
> The *double oxynitride layer*-producing embodiment may be particularly useful *where a very effective barrier layer is desired*, such as where very thin polysilicon gates (for example, less than about 150 nm) with *high boron dose implants* are used. ...

Aronowitz clearly teaches that Si layer **406** is first nitridized *and then oxidized* to provide a *nitrogen barrier to boron diffusion.*

The Examiner has provided no evidence or reasoning that Aronowitz' *intermediate* SiN layer **406 (Fig. 2D)** would *necessarily and inevitably* be an effective boron diffusion barrier without the additional oxidation as specifically taught at col. 8, lines 1-10.

Regarding **Claim 18**, the Examiner argues that Aronowitz discloses "*thermally annealing*" the silicon layer in a nitrogen-containing gas. See Office Action at page 4 (emphasis added).

> Re claim 18, Aronowitz et al. discloses a method of forming a nitride barrier layer, comprising the steps of: ....to form a silicon layer 206) [Fig. 2C] ***and thermally annealing****/nitridized the silicon layer in a nitrogen-containing gas* to form the nitride dopant diffusion barrier layer...

The Examiner has failed to indicate where Aronowitz teaches *'thermally annealing'* the silicon layer **206** (of Fig. 2C) to form SiN layer **206 (Fig. 2D)**

To the contrary, *as addressed above,* Aronowitz does *not* teach thermally annealing the silicon layer to form the SiN layer. The Examiner is again directed to Aronowitz at col. 5, line 57 to col. 6, line 34.

To form the intermediate silicon nitride layer **206 (Fig. 2D)**, Aronowitz *merely implants nitrogen* into the silicon layer. Aronowitz does not perform a thermal anneal in forming the silicon nitride intermediate material **206 (Fig. 2D)**.

The Examiner also argues that the limitation in the claims *'effective* to inhibit passage of a dopant therethrough' is merely functional language and/or intended use limitation in a method claim.

Claim 1, for example, is as follows:

> ...*exposing the silicon layer* to a nitrogen-containing gas *to nitridize the silicon layer to form a* continuous silicon nitride dopant *diffusion barrier layer* effective to inhibit passage of a dopant therethrough into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.

The Examiner is directed to **MPEP § 2173.05(g)** Functional Limitations (emphasis added):

> A functional limitation is an attempt to define something by what it does, rather than by what it is (e.g., as evidenced by its specific structure or specific ingredients). *There is nothing inherently wrong with defining some part of an invention in functional terms.* Functional language does not, in and of itself, render a claim improper. In re Swinehart, 439 F.2d 210, 169 USPQ 226 (CCPA 1971).
>
> *A functional limitation must be evaluated and considered, just like any other limitation of the claim, for what it fairly conveys to a person of ordinary skill in the pertinent art in the context in which it is used. A functional limitation is often used in association with an element*, ingredient, or step of a process to define a particular capability or purpose that is served by the recited element, ingredient or step....
>
> ...
>
> It was held that the limitation used to define a radical on a chemical compound as "incapable of forming a dye with said oxidizing developing agent" although functional, was perfectly acceptable because *it set definite boundaries* on the patent protection sought. *In re Barr*, 444 F.2d 588, 170 USPQ 330 (CCPA 1971).

Contrary to the Examiner's assertion, the term "*effective to inhibit passage of a dopant therethrough*" characterizes and defines the *structure* of the silicon nitride layer resulting from Applicant's method, *requiring the layer to have certain structural characteristics and qualities* -namely a structure that will inhibit dopant (boron) diffusion therethrough. This limitation, although functional, defines the boundaries of Applicant's method and the structure that results from that method.

Accordingly, full consideration of the limitation that the barrier layer be effective to inhibit passage of a dopant therethrough is proper and hereby requested.

In sum, for the above-stated reasons, Aronowitz does not teach or suggest Applicant's method of forming a nitride barrier layer as defined in the claims. Accordingly, the Examiner is respectfully requested to reconsider and then withdraw this rejection of the claims.

Rejection of Claims under 35 U.S.C. § 103(a) (Aronowitz/Muralidhar)

The Examiner rejected Claims 2-4, 9-14, 16-17, 19-21, 104-105 and 112 as obvious over Aronowitz in view of Muralidhar (USP 6,297,095). This rejection is respectfully traversed.

The Examiner maintains that Aronowitz is "silent" regarding the 'claimed conditions' and cites to Muralidhar for disclosing various process parameters as defined in the claims, citing to Figs. 23-25 and col. 16, lines 19-36, for forming a silicon nitride "barrier" layer **106/107**. The Examiner argues that it would have been obvious to utilize the processing conditions described by Muralidhar in the method of Aronowitz in order to form a barrier layer.

The Examiner further argues that SiN layer **106/107** is *intrinsically* effective to inhibit passage of a dopant therethrough. In support of that proposition, the Examiner cites *generally* to Figs. 1-28 and cols. 1-22, i.e., the *entire* disclosure of Muralidhar.

Muralidhar's nitride layers **106/107** are only taught as a barrier to *oxygen* – *not* as a dopant barrier. This is clearly stated by Muralidhar at col. 17, lines 1-12 and 28-40 (emphasis added).

> ...By including the encapsulation layer **106**, *oxidation* or other degradation *due to oxidizing ambient exposure* of the nanoclusters **104** can be reduced or eliminated. As such, the diameter

of the nanoclusters **104** is maintained, and no uncontrolled increase in the underlying tunnel dielectric occurs.

> ...
>
> The thin nitride layer **107** illustrated in **FIG. 25** forms a *barrier to oxygen* such that both the nanoclusters **104** and the underlying semiconductor substrate **100** below the tunnel dielectric layer **102** are *protected from oxidation*. As such, the potential for an increase in the thickness of the tunnel dielectric layer **102** is reduced.

There is no teaching in Muralidhar of SiN layer **106/107** as an effective dopant barrier.

Furthermore, Aronowitz is *not* silent as to the processing conditions for forming the intermediate silicon nitride SiN layer **406 (Fig. 2D)**.

Aronowitz particularly teaches using a process to produce a decreasing nitrogen gradient from the surface of the silicon film to the underlying oxide interface. And, to that end, Aronowitz specifically teaches the use of a *low energy nitrogen plasma implantation* to nitridize the silicon film with specific processing conditions for implanting the nitrogen. See at col. 6, lines 23-37 (emphasis added).

> For example, a LAM 9400SE reactor may be operated according to the following process parameters to achieve nitridization of a thin amorphous or poly silicon film deposited on an oxide, according to a preferred embodiment of the present invention: *pressure of about 10 mtorr; N_2 flow rate of about 10 standard cubic centimeters per minute (sccm); TCP power of about 200 W; bias power of about 10 W; electrode temperature of about 60°C.; backside He pressure of about 8 torr; step time of about 10 minutes. Using these parameters, a plasma with about 10 eV nitrogen species may be produced resulting in nitridization of the thin silicon film to about 25 to 30 atomic percent.*
>
> FIG. 3 shows a three-dimensional representation of the results an electron spectroscopic chemical analysis (ESCA) *for a low energy nitrogen plasma implant using the parameters described above.* The vertical axis represents atomic percent of nitrogen, and the side axis represents the depth of the thin silicon layer, starting from the surface and moving down. The horizontal axis represents the binding energy of core electrons. *The results demonstrate that nitrogen is implanted according to a gradient from the surface of the silicon film, which is about 20 atomic percent nitrogen, to the interface with the oxide, which has very little or no nitrogen content.* These results illustrate another useful feature of the present invention, which is that the nitrogen which hardens the dielectric layer is isolated from the underlying oxide and substrate layers and does not affect their performance.

Furthermore, following the nitridization step, Aronowitz teaches oxidizing the intermediate SiN layer **206** of **Fig. 2D** to convert it into a nitrogen-rich oxide (SIO_xN_y) layer **206** in **Fig. 2E**.

In contrast, after forming the SiN layer **106/107** on the silicon nanoclusters **104**, Muralidhar teaches depositing a dielectric layer **108** to encapsulate the nanoclusters. See col. 17, lines 1-12 and Fig. 24.

One skilled in the art reading the requirements of Aronowitz's processing to form a silicon nitride *intermediate* layer with a decreasing nitrogen gradient, which is then subsequently subjected to an oxidizing process to form an SIO_xN_y layer as a dopant barrier would not modify the processing parameters of Aronowitz based on Muralidhar's teachings as proposed by the Examiner.

Moreover, the Examiner has failed to establish that the proposed modification of Aronowitz with Muralidhar would intrinsically or inherently result in a silicon nitride layer as an effective *dopant barrier*. There is no teaching in Muralidhar of SiN layer **106/107** as an effective dopant barrier.

Accordingly, the Examiner is respectfully requested to reconsider and then withdraw this rejection of the claims.

Extension of Term.

The proceedings herein are for a patent application and the provisions of 37 CFR § 1.136 apply. Applicant believes that no extension of term is required. However, this conditional petition is being made to provide for the possibility that Applicant has inadvertently overlooked the need for a petition for extension of time. If any extension and/or fee are required, please charge Account No. 23-2053.

It is submitted that the present claims are in condition for allowance, and notification to that effect is respectfully requested.

Respectfully submitted,

Kristine M. Strodthoff

Dated: December 15, 2010

Kristine M. Strodthoff
Reg. No. 34,259

WHYTE HIRSCHBOECK DUDEK S.C.
555 East Wells Street
Suite 1900
Milwaukee, Wisconsin 53202-3819
(414) 273-2100

Customer No. 31870